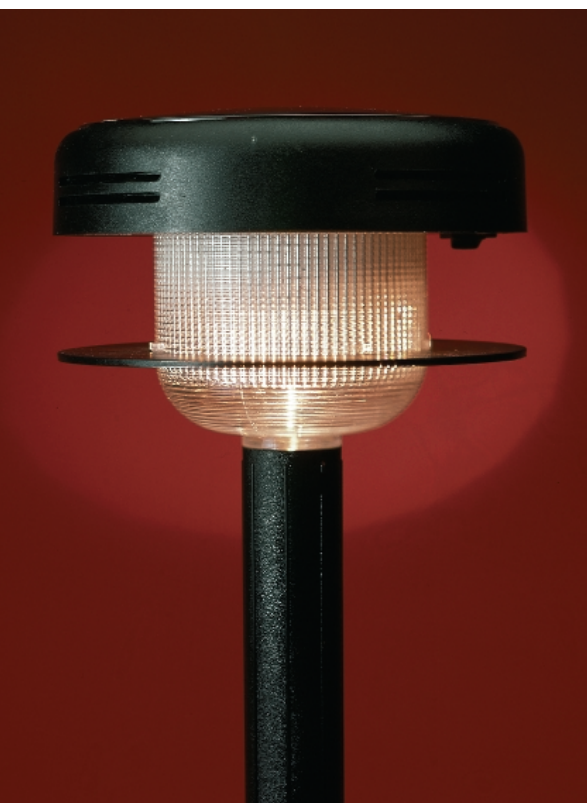


Garden Lighting

using solar cells

by K. Walraven and S. van Rooij

Completely 'self-supporting' garden lamps using solar cells as their energy source are gradually becoming more and more common. How do they actually work? We took one apart to find out.



From environmental and technical considerations, buying such a solar-cell garden lamp has a lot to recommend it. It's a great thing that the energy necessary for the lamp to burn in the evening can be drawn from the sunlight that is available for free during the day. In addition, such a lamp is enormously practical, since you can place it in any desired location in the garden without having to dig a trench through the lawn or flowerbeds. You are also free to change your

mind about the best location for the lamp — something that would have unpleasant consequences with ordinary garden lamps.

What makes up a typical solar-cell garden lamp? A certain number of elements are in any case necessary for it to function.

It's clear that there must be a *light bulb* and some *solar cells*. However, the bulb is naturally not powered directly from the solar cells, so there must be a *storage battery* and a suitable *charging circuit* to allow the battery to be charged by the solar cells. In addition, the idea is that the lamp should only burn during the evening and the night, and that needs a *twilight switch* with a light-sensitive cell. It's not necessary to do anything to switch off the lamp, since that happens automatically as soon as the battery is fully discharged.

Some of the more luxurious models have a small fluorescent tube in place of a normal light bulb, and in this case a small converter is also necessary. However, the model that we examined contained a small 2.5-V/75-mA halogen bulb, and thus did not need a converter. As far as the electronics are concerned, the whole thing can thus remain very simple.

Simplicity wins out

Our garden lamp consists of a simple plastic structure. Eight solar cells are

mounted at the top, and inside there are a small halogen bulb, two pen-light NiCd cells and a small printed circuit board for the electronics. As can be seen from **Figure 1**, there isn't all that much inside. This lamp costs around 15 pounds, and it can be found in several different shops.

The electronics also turn out to be extremely simple. **Figure 2** shows the complete schematic of the internal circuitry. The twilight switch is on the left, and its output controls the lamp via transistor T4. To the right are the on/off switch, a diode and the eight solar cells.

Charging

During the day, as long as there is sufficient light, the voltage generated by the solar cells is 8×0.45 V under ideal conditions, with a current that depends on the size of the cells — in this case, approximately 140 mA. With less light, less current is supplied. The charging circuit consists simply of a single Schottky diode (D1). The current generated by the solar cells passes through this diode, with its typical low voltage drop of 0.3 to 0.4 V, and charges the NiCd cells.

There is no overcharge protection. It is not actually necessary, since all NiCd cells can handle a continuous charging current equal to 1/10 of their capacity (60 mA in this case), while modern cells are so robust that



Figure 1. Once the lamp has been opened up, you can see that there's not very much inside.

twice this amount of current does not cause any problems. The advantages of using a somewhat higher charging current are naturally that the battery is already fully charged after several hours of sunlight, and that a certain amount of charging takes place even on rainy days and during the winter. Solar cells act as light-dependent current sources, so the more light there is, the more current they produce. The voltage is determined by the load, but it can never be higher than the previously

mentioned 0.45 V per cell.

Approximately 2.8 V is necessary to charge two NiCd cells. If we add the voltage drop across D1, we arrive at a required voltage of 3.2 V. This is 0.4 V per solar cell.

Charging takes place continuously, even when switch S1 is off. It is important to make sure that both NiCd cells are fully charged the first time. Otherwise, one cell may become fully discharged before the other one when they are discharged. As a result, this cell may have a

reverse-polarity voltage applied to it, which will shorten its useful life. Therefore, when first putting the lamp into service, you should place it outside with S1 switched off for at least one day in full sunlight, or two days if the weather is cloudy.

Burning

When S1 is closed, voltage is applied to the part of the circuit containing the light bulb.

An LDR is used to determine whether it is light or dark outside. During the day, the resistance of the LDR is low, and the voltage on the base of T1 is also low, so that it is cut off. T2, T3 and T4 are then also cut off, so that the bulb is not illuminated. As soon as it becomes dark, the resistance of the LDR increases, and the voltage on the base of T1 rises. T1 starts to conduct when the voltage is around 0.65 V. This causes T2, T3 and T4 to conduct as well, and the lamp starts to burn. T1 then receives a bit of extra current via R4, so that positive switching takes place when the circuit is sitting 'on the edge'. This is called hysteresis. It means that a threshold is set such that the light level has to drop a bit more before the lamp will switch on again once it is off, and vice versa. This means that the circuit does not react to every passing cloud or insect that is flying around.

As long as it remains dark, the lamp continues to burn until the battery is fully discharged. A fully charged battery has a capacity of 600 mAh, which is enough to supply the 75-mA bulb for approximately eight hours. This is sufficient for the evening and a large part of the night. In the winter, this is not possible, since the battery will probably not be fully charged due to a lack of sunlight.

When the battery becomes fully discharged, its voltage drops. If the voltage drops below 1.25 V, T2 and T3 are cut off, since their base-emitter junctions are in series and thus need at least this amount of voltage. The lamp is then switched off, and the battery is not further discharged.

In the long term

NiCd batteries usually have a lifetime of around 500 to 1000 charge/discharge cycles. After two to three years of continuous use, therefore, the two penlight cells of the garden lamp will probably be ready for replacement. However, these cells are presently so inexpensive that this is not a serious disadvantage. Naturally, there is also a limit on the lifetime of the light bulb, but here again, making a replacement is quick and inexpensive.

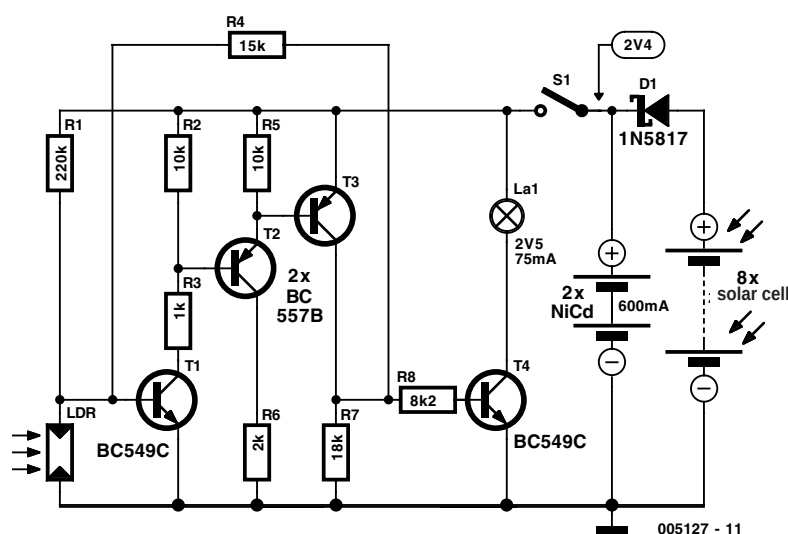


Figure 2. The necessary functions are provided by some very simple electronics.

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